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ABSTRACT

To explore and characterize the problem-solving processes of experts evaluating and revising text/illustration combinations, a study was conducted with experts from three different fields. Participants, who included five subject matter experts (SMEs) in biology, five professional designers, and five editors, were asked to diagnose and address problems in mismatched visual and verbal information in text and illustration combinations from textbooks. Instructions asked each participant to revise the combinations so that the match between them would make the information easier for a 10th grader to understand. Analyses of their responses reveal that, despite some similarities, experts from different disciplines have different motivations and strategies to guide their revisions. Editors were most acutely aware of the other collaborators working with text, while SMEs were primarily concerned with the students as an audience. These differences in rhetorical constraints seem to have affected the revisions that the experts chose to make. Results support the importance of prior knowledge and rhetorical constraints in visual/verbal problem solving. (Contains 37 references.) (SLD)

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ED 363 293

Problems in Picturing Text

by
Philippa Jane Benson

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BACKGROUND TO THE TEXT/ILLUSTRATION STUDY

Over the past quarter century, communication technologies have spawned an explosion of possible ways in which linguistic (i.e., text) and non-linguistic (i.e., visual displays/ illustrations) information can be combined for different purposes (McLuhan, 1964; Goody, 1987). In our daily lives, we encounter a myriad of mixed visual and verbal messages: illustrated textbooks, icon-laden computer interfaces, print and television advertising, and instructional manuals. At the same time, the large-scale reproduction and distribution of visual and verbal patterns has strongly influenced the degree to which these patterns can and are becoming social conventions (Ong, 1982; Kostelnick, 1990).

As information is increasingly transmitted via combinations of linguistic and non-linguistic forms, a topic of concern is the development of well-integrated visual and verbal representations of information. To date, studies have looked at issues related to but not directly addressing this topic. For example, extensive research has been done on the cognitive processes used by both experts and novices as they create and revise text (Hayes & Flower, 1980; Graves, 1985; Bereiter & Scardamalia, 1987; Hayes et al., 1987). In a similar vein, other researchers have focused on the process of design and of designers (Broadbent, 1979; Buchanan, 1985; Ballay, 1987; Kostelnick, 1989). Still others have investigated the relationship between the presentation of visual and verbal information and reader comprehension (Schallert, 1980; Bluth, 1981; Hayes & Readence, 1983; Abel & Kulhavy, 1986; Larkin & Simon, 1987; Levin, Anglin, & Carney, 1987), while yet others have looked at the relative comprehensibility of different kinds of illustrations (Peeck & Goud, 1980; Szlichcinski, 1980; Levie, 1987; Reynonds & Baker, 1987).

Little research, however, has directly explored the processes people use or the rhetorical constraints people consider when integrating visual and verbal representations of the same information. Rhetorical constraints could include consideration of the intended readers of and purposes for the integrated information, of others preparing the information, or of those who will use the information to inform, instruct, or persuade.

Bearing in mind the wide use of combined visual and verbal information in modern society, research in this area is a significant next step to take in rhetorical studies. First, by uncovering and understanding more about the processes people use to diagnose and address problems in integrated visual and verbal forms, we can understand more about the specific roles rhetorical constraints play in the development and interpretation of visual/verbal combinations. Second, such studies will allow us to more fully understand interactions in visual and verbal problem-solving. Finally, these kinds of studies may help us move toward a richer notion of "literacy," one that includes facility in comprehending and producing integrated visual and verbal forms.

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AN OVERVIEW OF THE TEXT/ILLUSTRATION STUDY

The participants

To explore and characterize the problem-solving processes of experts evaluating and revising text/illustration combinations, I conducted a study using experts from three different fields. The participants were asked to diagnose and address problems in mismatched visual and verbal information in text/illustration combinations. The study included five subject matter experts [biologists] (SME), five professional designers (D), and five editors (E). These experts were selected because all had high levels of expertise in their respective areas, had been working in their fields for between five and twenty years, and had experience collaborating with others in the development, production, and/or evaluation of illustrated instructional texts. In addition, all the subject matter experts (henceforth SMEs), three of the editors, and four of the designers were either currently teaching or had previous teaching experience.

The text/illustration combinations

For the purposes of this study, text/illustrations combinations from textbooks were chosen to represent combinations of visual and verbal representations of the same information. Fixed print combinations of text and illustration were chosen for several reasons. First, they are the kinds of text/ illustration combinations that are pervasive in instructional materials and are known to be as often confusing as clarifying for readers (Pressley et al., 1983). Second, a strong base for this study is provided by previous research on reader comprehension of print text/illustration combinations which suggests that well-matched texts and illustrations can aide learning (Willows & Houghton, 1987). The topics of the text/illustration combinations chosen for the study were

1) the life cycle of a species of fern,
2) the life cycle of a kind of fungus, and
3) the movement of glaciers during the ice age (see Figure 1).

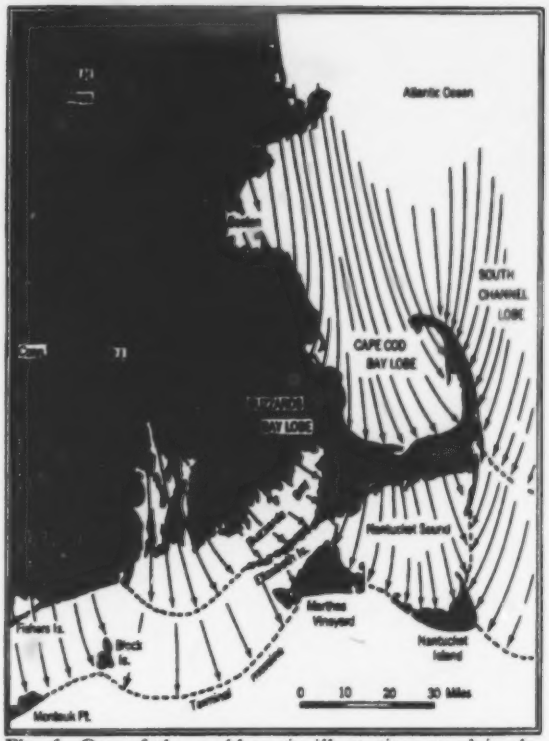

Fig. 1: One of the problematic illustrations used in the study (Strahler, 1966).

These three particular combinations were chosen because they

- came from widely-used instructional texts and focused on topics that virtually every high school science student will encounter: the ice age, and life cycles of two different life forms, molds and fungi.
- contained visual and verbal information mismatched in ways typical of text/ illustrations combinations found in instructional texts. Mismatched information could include, for example, information that is topically prominent in a text but is not in the illustration, or objects or processes highlighted in the illustration but that are not mentioned in text. A variety of mismatched or missing information was present in all three text/illustration combinations in the study.
- can be considered different by type (Levin, Anglin, & Carey, 1987): one is representational, reinforcing major events described in the text; another is organizational, representing the organizational framework of the text; the

third interpretational, using non-exact pictorial analogies to make abstract concepts in the text more concrete and accessible.

These different kinds of illustrations were included in the study to obtain a fairly broad representation of types of problematic text/illustration combinations and thus avoid narrow conclusions, including the potential problem of uncovering expert problem-solving strategies that might be associated only with one type of illustration or one category of mismatched information.

The design of the study

Each expert was given three different problematic text/illustration combinations to revise, for a total of forty five revision sessions (see Figure 2). Participants were presented with the combinations in counterbalanced order within groups to avoid both learning and fatigue effects in the final data.

	SME	Designer	Editor
Fern	5	5	5
Fungus	5	5	5
Ice	5	5	5

Fig. 2: Each participant revised three text/illustration combinations.

In addition to the expert participants, fourteen first year university students read and interpreted the text/illustration combinations. Space limitations precludes this part of the study being discussed in detail in this paper.

COLLECTING THE DATA

Experts' revision task

Concerted efforts were made in the design of this study to create a task that was not artificial; according to pilot studies and preliminary conversations with the participants, the task of individually reviewing text/illustration combinations (ones created by others) was a realistic task for them. In fact, most participants said that although illustrated texts were sometimes reviewed or refined by collaborative teams, the task of individually reviewing text/illustration combinations was a familiar one, one they considered part of their professional work. However, to underscore the collaborative nature of the textbook publication process, the instructions reminded participants that others involved in the publication of the final book would be reviewing their work.

The task instructions asked participants to revise each text/illustration combination to improve the match between the text and illustration in a way they felt would make the information easier for a tenth grade reader to understand. The instructions stated that participants could make any revisions they wanted and informed these experts that their draft revisions would be given to other revisors as a model of an effective text/illustration combination. Participants were allowed to spend as much time as they wished to complete each task.

Data collection

Before beginning the actual revision tasks, each of the fifteen experts was allowed to practice thinking aloud while working. After the practice sessions, they were given their task instructions, the text/illustration combinations, and sheets of blank paper and colored pens to use in making revisions. Experts were tape recorded as they thought out loud while revising the text/illustration combination/s. (Each transcribed problem-solving session is referred to as a *protocol* and the process of examining them *protocol analysis* [Newell & Simon, 1972]). Some experts revised the text and/or illustration on the original materials, while others used the blank sheets to write or sketch complete new material. Experts took between twenty minutes to over two hours to complete each revision task. Most experts spent about an hour revising each combination.

CODING THE DATA

Preparation of protocols

The tapes of the expert revision sessions were transcribed and typographically marked to indicate when a speaker was either reading, rereading, writing, or drawing (boldface indicated reading, underline signalled rereading, italics was writing or drawing, plain type indicated commentary). If subjects were

drawing, the drawing's location was indicated in parenthetical notes in the transcripts. Together these materials provided a record of how participants interpreted both the text and the illustration in each combination, as well as how they detected, diagnosed, and/or addressed different kinds of visual or verbal problems.

The transcripts of the protocol sessions were segmented into episodes, ranging from a few words to lengthy narratives, which were checked and agreed upon by two coders. Similar to the motivation of Newell and Simon (1972), the purpose of separating the protocols into episodes was "to focus attention on the features of behavior that are most relevant to assessing a subject's problem solving abilities" (p. 284). Coders judged episode boundaries to be where subjects changed their focus of attention from one activity to another according to the coding scheme described below. If reading, rereading, writing, drawing were part of a larger activity, these sections were incorporated into the overriding episode in the transcript.

Coding scheme

The transcriptions were coded according to a coding scheme designed to capture general high level activities and to capture details of the experts activities as they work with the text/illustration combinations. Figure 3 shows the fourteen specific codes associated with the four primary coding categories of meta-codes, co-codes, text codes, and design/illustration codes.

General comments not directly related to the task (such as "This is tiring!") as well as comments related to planning or consideration of task were marked as meta-comments (C, Proc, Task). The audience or match co-code (Aud, M), along with either a text or illustration code, marked comments that included consideration of audience or that indicated the expert was trying to match information between the text and illustration. When participants were focusing on the text, their comments were marked with one of the five text codes (TC,TI,TL,TD,TS) and when they were focusing on the illustration, their comments were marked with a design/ illustration code (DI, DL, DD, DS).

Text/illustration codes

Meta-codes

C	Catch all, for meta-comments
Proc	Planning or accounting of process
Task	Consideration of task

Co-codes

Aud	Consideration of audience
M	Indicate matching of information between text and illustration

Text codes

TC	Context of material
TI	Interpreting meaning of text
TL	Detecting and/or Diagnosing problem based in text language
TD	Detecting and/or Diagnosing problem based in design of text
TS	Planning, executing, or revising solution for text-based problem

Design/Illustration codes

DI	Interpreting meaning of illustration
DL	Detecting and/or diagnosing problem based in language in illustration
DD	Detecting and/or diagnosing problem based in design of illustration
DS	Planning, executing, or revising solution to illustration-based problem

Fig. 3: The coding scheme used for the study.

This coding scheme is based on the idea that every text/illustration combination has both linguistic and non-linguistic components. For the purposes of this study, "non-linguistic" information refers to graphic elements of visual displays including illustrations, typography, and page layout. Here, "linguistic" information refers to text as written discourse. In this context, text refers to printed English language and illustration refers to drawings that accompany texts. However, a text can include non-linguistic features such as variations of typographic cues (e.g., use of boldface or italic type styles) and an illustration can include text features such as labels. Therefore, as illustrated in Figure 4, the texts and illustrations in this study both have visual and verbal components. In the coding scheme, both the text and the design codes consider verbal and visual information.

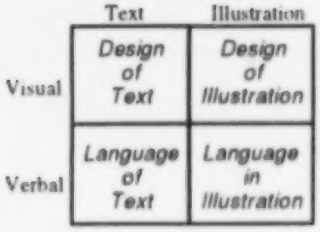

Fig. 4: The texts and illustrations used in this study have both visual and verbal components.

ANALYZING THE DATA

I conducted three analyses on the data collected from the protocols of the experts as they revised the text/illustration combinations. One of analysis used counts from the main categories of the coding scheme to look for relationships among how much individuals said, the revision task they were doing (e.g., which t/i combination), and the group they belonged to (e.g. designer, editor, SME).

The second analysis looked at data reflecting the extent and manner in which subjects considered audience (both students and collaborators) as they did their revision work. Data reflecting the problems experts found in the text/illustration combinations was also analyzed.

Log-linear models

To analyze the data concerning the strategies of different experts, log-linear analyses were used to model the data from the main coding scheme. I used log-linear models rather than more traditional (e.g. ANOVA) analytical methods first because the study was exploratory and, therefore, not designed to test any particular hypotheses and, second, because the data was categorical. Log-linear analyses are designed to test, or attempt to "fit," statistical models to categorical data, with each model representing a different description of relationships between categorical variables. Statistical methods used in log-linear modeling are also appropriate to use when one wants to look for possible interactions among variables. Thus, log-linear modeling promised to be useful in bringing to the fore relationships among the revising behavior of individual participants (as reflected by the coding scheme), the text/illustration combination being revised, and the group to which each individual belonged.

To explore possible relationships between the fifteen subjects, the three tasks (Fungus, Ice, Fern), and the subject by group (Designers, Editors, SMEs), log-linear models were constructed to compare how much was said about a problem (amount of commentary) and how subjects' comments were distributed among the meta, audience, text, and design codes (pattern of commentary). Taken together, models of individual's amount and pattern of commentary indicated that

- subjects and tasks jointly determine how much is said,
- how revising attention is allocated among the activities represented by the codes (meta, audience, text, and design) is determined only by the subject, and
- subjects themselves behave relatively consistently across tasks.

Another model explored the possible influence of expert group on the amount or pattern of commentary during revision. This model assumed that every subject within a group was like every other subject. The results indicated that a relationship existed between group and pattern of commentary, although it could not be seen at a very fine grain. In other words, given that subjects can vary within groups, grouping does have some effect on the pattern of responses, even though this analysis does not allow us to see that effect very clearly.

Considering group as a variable is valuable because it allows us to predict how other persons might behave based on which group they were in. In other words, we hope to find a measure of what makes Group A like Group A: designers like designers, editors like editors, subject experts like subject experts. Although the log-linear analyses suggested that the expert groups did cohere as groups, the results also indicated that much more subtlety needs to be included in any characterization of expert revision behavior.

The next two sections describe how the study accomplished the goal of describing the subjects' revisions at a more fine grain by

looking at how experts considered audience and how they identified problems.

Expert's perception of audience

A second analyses looked at data from the coded protocols reflecting the extent and manner in which subjects considered students and collaborators as audiences for their revision work. Based on the previous analysis and in pursuit of more precise understandings of what makes individuals distinguishable by group, the analysis was designed to weed out differences in how each group considered audience as they revised.

As shown in Figure 5, across all tasks the fifteen participants made a total of 177 comments referring to audience groups. Audiences considered by the experts included students as well as other designers, editors or writers, SMEs and, in a few cases, teachers. Designers, editors, and SMEs differed in terms of **how many** comments concerning audience were made, **when** these comments were made, **who** was considered as primary audience, and **what kinds** of considerations of audience were given priority.

Group	# of comments
Designers	36
Editors	56
SMEs	85

Fig. 5: The number of comments each expert group made about audiences.

The most obvious difference between the groups is **how many** comments were made about audience: SMEs accounted for almost one half of the comments, while editors accounted for about one third and designers for only about one forth.

Designers, editors, and SMEs also differed in terms of **when** they considered audience. Specifically,

- Designers consider audience most when diagnosing problems in text and when developing solutions to problems in design,
- Both SMEs and editors consider audience most when diagnosing and developing solutions to text problems, and
- Unlike designers and editors, SMEs consider audience when considering the context of use of the materials being revised.

SMEs again differed markedly from designers and editors in terms of **who** they considered as their audience of primary concern. Specifically, they were much more concerned with students as readers of their revisions (87% of their comments on audience) than with peer collaborators (13%). On the other hand, designers and editors approximately split their attention approximately evenly between students and collaborators.

Some similarities between the three expert groups appear when looking at the data on audience in terms of **what kinds** of considerations of audiences were made. For example, both designers and SMEs made general reference to student readers in about 20% of their comments, e.g,

> "I don't know if the students will see that..."

and another 20% of their comments were concerned with how the material would affect the motivation of student readers, e.g.,

> "You wonder if a student is going to get all the way from the top through all of these words."

Editors considered students' motivation only half as often as the designers and SMEs. The remaining comments that both designers (60%) and SMEs (58%) made about students centered on concern for students' prior knowledge

> "I think for this to be studied I have to assume that students already know diploid and haploid and know some idea of what that means in general...".

Editors also distinguished themselves from designers and SMEs by giving somewhat less attention to how the materials would affect the motivation of student readers and by giving more attention to consideration of collaborators as audience. Specifically, in just over half their comments about collaborators, designers and SMEs made general comments not referring to any specific collaborative group (i.e., other designers, SMEs, editors, or teachers) while over 60% of editors' comments about

collaborators were concerned with other editors or writers. In other words, as a group, editors appeared to focus on working with others on revising the text rather than on collaborating with others on design or on content.

In sum, the data indicates that consideration of audience during revision clearly distinguishes the three expert groups. The major findings showed that SMEs consider audience more often than do editors and designers, and that their revisions are guided more by considerations of end readers (in this case students) than by consideration of their collaborators. Unlike SMEs, editors revision strategies were more strongly affected by consideration of working on text with colleagues.

Expert's perceptions of problems

In a final analysis, data was compiled reflecting problems experts found in the text/illustrations combinations. To collect data on problems, comments reflecting experts' detection of problems were collected from all forty five transcripts. Problems were coded as falling into one of the four main coding categories, that is, problems with the text's language (TL), the design of the text (TD), the labels (e.g. language) in the illustration (DL), or the design of the illustration (DD). Problems were analyzed both in terms of the **how many** problems experts noticed and in terms of **what prompted** the expert to notice the problems.

The fifteen experts mentioned a total of 665 problems, as shown in Figure 6. Each problem was counted only once for each expert, regardless of how many times they mentioned it.

	Designers	SMEs	Editors
Text Language	99	126	131
Text Design	8	3	3
Design of Language	48	41	32
Illustration Design	81	47	46
	236	217	212

Fig. 6: Counts of problems experts found in each major code category.

Several differences among the groups can be seen from the raw counts. First, designers noticed approximately 20% fewer problems in the language of the text than did either SMEs or editors. On the other hand, designers noticed nearly 15% more problems in the design of illustrations than either SMEs or editors. Overall, however, despite moderate differences, the groups showed marked similarity, particularly the SMEs and the editors. First, each of the three groups accounted for approximately one third of the total number of problems detected, and the problems found in each category were in the same rank order for each group. In other words, in all three groups, experts detected the greatest number of problems in the language of the text, followed by problems in the design of the illustration, followed by problems in labelling problems, and problems in the design of the text. Third, all three groups detected more problems in single domain cells (e.g. verbal/verbal (TL), visual/visual (DD) than in mixed-domain cells (e.g., visual/verbal (TD), verbal/visual (DL)). Figure 7 illustrates single and mixed domain cells.

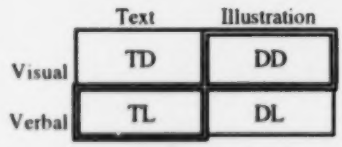

Fig. 7: The fully bordered TL and DD cells are single domain cells, TL concerned with information in only verbal (linguistic) form and DD concerned information in only visual (non-linguistic) form. The TD and DL cells are concerned with both visual and verbal information.

The differences between the three groups does not begin to become apparent until one looks at **what prompted** the experts to notice problems in the text/illustration combinations. To identify that which prompted experts to notice problems in the combinations, or the problem *source*, I reviewed the transcripts in terms of what experts were attending to as they articulated their perception of the problem. I coded three different kinds of problem sources: text as source (T source), illustration as source (D [for design] source), and prior knowledge as source (M [for memory] source). For example, a problem coded with a text source for a particular expert would be a problem articulated by that expert as she was reading (attending to) the text itself. (In the following examples, boldface mark text being read, underline notes

text being reread, italics marks text being written, and plain typeface indicates spoken comments.) For example

> **"If a spcre lands on a suitable surface such as another piece of bread it germinates and starts the cycle over again.** How long was that cycle? Is this happening at lunch or over a week? They're stressing how, how, how....the cycle and how many, but you're not telling me how long!"

Here, the recognition of problems in the text which were prompted by the text itself. Experts found the text problematic either through ambiguity or missing information in the text, or through confusing syntax.

On the other hand, a text language (TL) problem coded with its source in the illustration/design (D source) was a problem articulated by an expert as she was attending to the illustration. For example

> **"Notice on the map that the direction of ice movement is not everywhere the same.** There's no information on the map that says that. So I don't know how you can be expected to notice on the map, get that information from the map. It isn't on the map. So, I'm just going to encircle that sentence and question that. "

In the next example, an expert articulated a problem he recognized in the use of typographic cues (TD) after reading the text (T source).

> "Now why, why is some of this italicized? Why is rhizopus italicized here when it isn't italicized at the beginning of the paragraph?"

Other problems were coded as TD problems with their sources in the illustration (D).

> "Its not very easy to find the boldface words (those in the text) in the illustration."

Experts noticed labeling problems in the illustration (DL) both as they were attending to the text (T source),

> **"Its hyphae form a white cottony mycelium**...."What's a hyphae...this hypha is not labelled anywhere."

and as they were attending to the illustration (D source).

> "I'm going back to the diagram to see if it gives me any clues...There's, there's no title on it, which is really bad. "

Finally, experts mentioned problems they found in the overall design of the illustration (DD) both after reading the text (T source) and after evaluating the illustration (D source).

In addition to the features of the text or the illustration prompting the recognition of problems, experts also recognized problems simply based on their prior knowledge of the topics being discussed (M [for memory] source).

> "Each unit of protoplasm contains a nucleus...That doesn't mean anything... Um, there, I mean that's an artificial invention. There is no such thing. "

Problems coded with a prior knowledge source were ones experts immediately recognized without questioning or being confused by either the text or the illustration.

When the problem data is analyzed in terms of source, distinct differences between the expert groups begin to emerge (see Figure 8).

Designers

	Text	Illustration	Memory
Total #	152	83	1
% source	64.4	35.1	0.5

Editors

	Text	Illustration	Memory
Total #	157	52	3
% source	74.1	24.5	1.4

SMEs

	Text	Illustration	Memory
Total #	84	49	84
% source	38.7	22.6	38.7

Fig. 8: Number and percent of problems recognized by each group via text, illustration, and memory sources.

The first and most prominent difference is that SMEs relied on their prior knowledge (memory) to detect and diagnose problems in the text/illustration combinations substantially more frequently than either designers or editors. Across all three text/illustration

combinations, SMEs used prior knowledge to detect and diagnose almost 40% of the problems they noted, compared to 1.4 % for designers and .5% for editors. Even in the Ice text/illustration combination, whose content was farthest from the core expertise of most of the SMEs, these experts recognized problems based on their prior knowledge substantially more frequently (15%) than either designers or editors who, basically, did not use prior knowledge at all. Interestingly, in interviews after the revision sessions were complete, many of the experts (those in all three groups) said they felt they had some knowledge of the topics of the text/illustration combinations.

Another feature of the differences among the experts is that both designers and editors were routed to problems in the text/illustration combinations much more often via the text than by the illustration. In other words, designers were prompted to notice problems more by the text (64.4%) than by the illustration (35.1%); editors were prompted to notice problems more by the text (74.1%) than by the illustration (24.5%), but SMEs were prompted to notice problems comparatively less by the text (38.7%) and more by their prior knowledge (38.7%).

Student responses

As mentioned earlier, additional analyses of the data have looked at how the students' perceptions of problems in the text/ illustration combinations compare to those of experts. In short, the experts and students perceptions of problems in the text/illustration combinations differ dramatically. Although students did notice some of the features of the text/illustration combinations that the experts noticed as problematic, they also misinterpreted the texts and illustrations in ways completely unpredicted by experts. For example, in the Ice text/illustration combination (see Figure 1), one student incorrectly interpreted the text/ illustration as showing the glacial ice eroding land from the Cape Cod area, rather than depositing the material to form the peninsula. Another student interpreted the combination as showing the glacial flow creating the coastal outline of New England, which also is not correct. Other features of the text/illustrations predicted by the experts to be problematic for the students, such as an abundance of latinate words or lack of definitions, seemed not to bother most of the students at all.

LOOKING FORWARD

The analyses discussed in this article show that, despite some similarities, experts from different disciplines have different motivations and use different strategies to guide their revisions of text/illustration combinations. Among the most noticeable of these differences is that editors are acutely aware of the other collaborators working with text, while SME's are primarily concerned with student's as audience. These differences in rhetorical constraints seem to have affected the revisions that experts chose to make. Another difference between the three groups was that SMEs relied on their prior knowledge of the topical content of the text/illustration combinations to help them detect and diagnose problems; this strategy, however, did not lead the SMEs to detect any more or any different problems from either designers or editors.

To date, this study has yielded two preliminary conclusions. The first conclusion is that more detailed studies of individuals rather than groups may be the most productive route to follow in building comprehensive models of visual/verbal problem-solving behavior of both experts and novices. Closely linked however, is the second conclusion: prior knowledge and rhetorical constraints, such as the role of audience, play an important role in visual/verbal problem solving strategies, and thus are critical features to include in future studies.

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